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A fan

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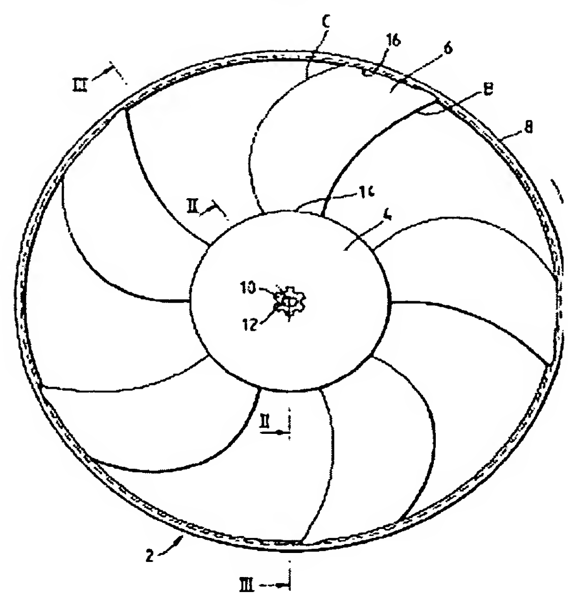
A fan comprises a hub (4) rotatable about a central axis and a plurality of blades (6) each having a root region (14) secured to the hub (4) and extending radially outwardly to a tip region (16). Each blade (6) is designed with particular characteristics to reduce noise without affecting the performance of the fan.

Fig. 1.



Description of corresponding document: **EP0583091**

The present invention relates to a fan, and particularly to an axial flow fan, for example a fan designed to cool air flowing through a heat exchange system in a vehicle.

Such axial flow fans are generally provided with a plurality of blades, each of which is secured at its root to a huk is driven by a rotating shaft and from which the blade extends radially outwardly. The blades can be spaced arour

the hub in a symmetrical or non-symmetrical fashion. Axial flow fans are known having blades of various design: Thus, the blades can be provided with a tangential sweep either in the forward or rearward direction, with variatic in pitch angle to suit particular applications. Furthermore, it is known to secure the blade tips to an outer circular which encloses the blades and is generally centered on the axis of rotation of the fan.

When used in a vehicular application, the fan can be arranged either to blow air through a heat exchange system i heat exchange system is on the high-pressure (downstream) side of the fan or draw air through the heat exchange system if the heat exchange system is on the low-pressure (upstream) side of the fan. Such fans can be made from moulded plastics or from sheet metal or a combination of the two.

The performance of the fan is or particular concern when used to cool air in an enclosed engine compartment. Mc particularly, it is required to reduce the noise generated by such fans without a reduction in their performance and efficiency. Another requirement is that the fan should be strong enough to resist the stresses applied to it at high f rates, and in adverse operating environments.

Reference is made to the following documents which describe fans designed particularly for vehicular cooling applications.

US-A-4358245, US-A-4569631 and US-A-4569632 disclose a fan of the general type with which the present invention is concerned and which has blades which are skewed forwardly or rearwardly or have a combination of forward and rearward skews to improve efficiency and reduce noise. GB-A-2178798 describes a fan having blade with a relatively more forwardly curved outer portion, said to reduce noise.

A first object of the present invention is to provide a fan having greater mechanical strength without loss of effici and flow performance characteristics as compared with the fans described in these prior art documents.

A second object of the invention is to provide a fan exhibiting lower noise.

According to a first aspect of the present invention there is provided a fan comprising a hub rotatable about an ax the centre of the fan and a plurality of blades each having a root region secured to the hub and extending radially outwardly to a tip region, wherein each blade has leading and trailing edges which each include a portion lying tangential to a respective radius extending from the centre of the fan.

In one embodiment, the leading and trailing edge each have a portion at the root region of the blade which extend tangentially to a respective radius extending from the centre of the fan for a distance along the length of each of tl leading and trailing edges which lies between 5% and 10% of the total length. Thereafter, the leading and trailing edges curve continuously in a forward or rearward skew.

The provision of a linear portion at the root region which extends tangentially to a radius increases the strength of blade at the root portion. In known fans, a common failure location is the root region and one of the reasons for th that in most fans, the blade curvature away from the radius of the fan begins immediately at the root region. By reducing the curvature at the root region, less stress is applied to the root region of the blade in operation of the fa and thus the fan has a greater mechanical strength there. The inventor has discovered that the root portion of the b does not have any significant effect on air flow through the fan and so, contrary to conventional wisdom, it does r have to have a high angle of skew to be effective.

In another embodiment, the tangential portion of the leading and trailing edges lies at a point between the root reg of the blade and a point lying 50% along the length of the leading and trailing edges. The leading and trailing edg are skewed in one direction from the root region, the direction of skew being changed at the tangential portion.

The provision of forward and rearward skews in this way reduces noise generated by the fan due to the changes ir flow which arise as it passes over the blade. This phenomenon is known in the art, for example see US 4569631.

According to a second aspect of the present invention there is provided a fan comprising a hub rotatable about an at the centre of the fan and a plurality of blades each having a root region secured to the hub and extending radial outwardly to a tip region, wherein each blade has a root chord width, the chord being taken across an arc defined the radius of the hub and the contact points of the leading and trailing edges with the hub, which is not greater tha the chord width at the tip region, the chord at the tip being taken across an arc defined by the radius of the fan anc contact points of the leading and trailing edges with that arc.

The provision of a chord width at the root region which is less than or equal to the chord width at the tip region enables the amount of material at the root region to be reduced, and thus reduces stress concentration at that point a blade of given mass it is of benefit to distribute the masts according to the workload of the blade in its different regions. As the largest part of the flow occurs over the outermost 30% or so of the blade, the mass can be concentrated here and accordingly reduced at the root portion.

Preferably, the chord length increases gradually from the root region of the blade over a first portion of the span o blade and then decreases rapidly over a second portion of the span of the blade. The blade projected width similai increases and then decreases. In the preferred embodiment, the first portion extends for a distance lying between 50-70% of the blade span.

According to a third aspect of the present invention, there is provided a fan comprising a hub rotatable about an a at the centre of the fan and a plurality of blades each having a root region secured to the hub and extending radial outwardly to a tip region, wherein each blade has a surface which is curved so that the dihedral angle varies along span of the blade moving from the root to the tip, the dihedral angle being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan. In the preferred embodiment, the dihedral angle decreases moving from the root to the tip over a first portion of the span of the bl. said first portion being between 65-75% of the total span and then stays constant or gradually increases for the remainder of the span of the blade.

As the dihedral angle reduces, there is a greater proportion of linear flow in the compound air flow across the bla(As the maximum load is taken on the outer part of the blade span, it serves to reduce noise generation if a large p: this flow is linear.

The combination of the first and third aspects of the present invention provides a blade having both dihedral and tangential sweeps which enhances broad band noise reduction over the frequency spectrum.

Preferably, the tip region of the blade are secured to an outer annular band which improves the structural integrity the fan. In this case, it is preferred if the leading edge of the blade at the outermost radius is tangential to the curv: of the band to reduce boundary layer separation at the outer part of the fan.

In the preferred form, the fan is formed as a single, integral unit. That is, the fan can be formed of a high strength plastics material which can be injection moulded to provide the hub, the blades and the band, when present, as a common moulding.

For a better understanding of the present invention and to show how the same may be carried into effect, referenc will now be made by way of example to the accompanying drawings, in which:
Figure 1 is a plan view of a fan seen from the front;
Figure 2 is a cross-section taken through the hub of the fan along line II-II in Figure 1;
Figure 3 is a view which is part-section taken through the fan and part perspective view to show the attachment o: blades to the hub (line III-III in Figure 1);
Figure 3a is a view of the tip of a blade secured to the outer annular band;
Figures 4a, 4b and 4c illustrate diagrammatically the sweep, dihedral and pitch respectively of a blade;
Figure 5 is a plan view of a hub insert;
Figure 6 is a section through Figure 5 along the line VI-VI;
Figure 7 is a section through Figure 5 along the line VII-VII;
Figures 8 and 9 are axial plan elevations of a blade;
Figure 10 is a section taken through a blade illustrating the change in dihedral along the span of the blade;
Figure 11 is a graph showing the variation of velocities along the blade span;
Figure 12 is a graph showing the variation of projected width of the blade with respect to blade span;
Figure 13 is a graph showing the variation of blade width with respect to blade span;
Figure 14 is a graph showing the variation of blade thickness with respect to blade chord;
Figure 15 is a graph showing the variation of chord angle with respect to blade span.

Figure 1 shows in plan view a fan 2 which includes a centrally located cylindrical hub 4 with a plurality (five as illustrated) of blades 6 extending outwardly therefrom to a cylindrical outer rim or band 8.

The hub 4 carries at its centre a hub insert 10 which defines an aperture 12 for accepting a shaft which mounts th(for rotation around its central axis. The outer band 8 encloses the blades and is generally centered on the axis of rotation of the fan 2. Each blade 6 extends from a root region 14 secured to the hub 4 to an outer (or tip) region 1(

secured to the inner surface of the band 8. The tip region 16 of the blades 6 are joined to the band over the full wi of the blades and not at a single point or over a narrow connecting line. This increases the strength of the structur

The outer band 8 of the fan adds structural strength to the fan by supporting the blades at their tip and also serves hold air on the working surface of the blades. The band 8 is of uniform thickness but has a frontmost section 8a w is curved to form a funnelling effect, as shown in Figure 10. This rounding of the band 8 reduces losses due to vortices in the gap between the fan and a shroud surrounding the fan. The band 8 furthermore provides a uniform flow passage for air flow passing through the fan and decreases unwanted variation in the dihedral angle rho (Fig 4b) and the pitch angle alpha (Figure 4c) of the blade.

The blades 6 are shaped so that they are secured to the band 8 with the leading edge B tangential to the frontmost curved section 8a. This can be seen in Figures 3 and 3a.

In use in a vehicular application for engine cooling, the fan can be positioned in front of or behind an engine cool heat exchanger system comprising for example a radiator, condenser and oil cooler. The fan can be arranged so th air is either blown through the heat exchanger system if the heat exchanger is on the high pressure (downstream) : of the fan, or drawn through the heat exchanger system, if the exchanger is on the low pressure (upstream) side o fan. The fan 2 is preferably used in conjunction with a shroud that extends between the radiator and the outer edg the fan. The shroud serves to prevent the recirculation of air around the outer edge of the fan from the high pressu region at the downstream side of the fan to the low pressure region at the opposite side of the fan adjacent the radiator.The shroud can be any suitable structure which blocks this recirculation flow. One known structure is funnel-like as shown for example in US-A-4,358,245.

Reference will first be made to the design of the hub having regard to Figures 2 and 3. The hub comprises a plast moulded body section 18 which defines an outer cylindrical ring 20 and an inner cylindrical ring 22. The inner an outer rings define between them an annular space 21. The inner cylindrical ring 22 has an internal annular ledge 2 provided for supporting a hub insert 10 as described in more detail hereinafter. The hub insert 10 is shown in mo detail in Figures 5 to 7. The insert can be made of a plastics or metal material and comprises a solid walled cylind 26 provided around its periphery with a plurality of protrusions 28 which form a castellated outer surface. The ins 10 defines an aperture 12 in the form of a flat sided oval, that is having end portions 30 formed by respective arcs circles and side portions which are linear The linear side portions 32 assist to holed a shaft inserted into the apert 12 against rotation with respect to the hub insert 10. The castellated outer surface of the hub insert 10 enables the insert to be connected to the plastics moulded section 18 of the hub in a single manufacturing step. That is, a mou defining the plastics moulded body section 18 is provided in which the hub insert 10 is placed. Plastics material is injected into the mould in a known injection moulding process and enters the regions 27 (Figure 7) in the surface the hub insert between the protrusions 28. Thus, a secure mechanical connection is provided between the hub ins 10 and the plastics moulded section 18.The hub insert 10 provides a better fit and thus reduces the play between a shaft inserted into the aperture 12 and the insert 10. This thus helps preserve the fan balance when rotating and reduces the drift of the fan from true axial rotation.

The annular space 21 can accommodate the front plate of an electrical motor provided to drive the shaft and thus protect the motor from the intrusion of moisture and dust.

The fan hub 4 is designed to approximate to a bowl shape which is more rounded than the straight cylindrical hub the prior art. More particularly, the hub outer surface has a central shallow depressed region 15 flanked by a substantially straight angled annular region 50. This annular region leads to a substantially flan annular region 52 which then curves into a radius 54 which passes into an outer cylindrical surface of the hub. The elimination of a sharp angle at the front part of the hub reduces losses due to vortices forming at the hub surface. This so called "vortex shedding" causes undesirable turbulence in the flow in the-region of the hub.

The minimum width of the hub in the axial direction is at least equal to the blade width at the root of the blade 6. distance between planes P1,P2 passing through the rear of the hub 4 and of the outer band 8 respectively and perpendicular to the axis of rotation may vary up to 50% of the axial extent a, of the band 8. A plane P3 passing through the front of the hub and perpendicular to the axis of rotation may coincide with a plane P4 passing throug the front of the band.

The hub moulded section 18 is provided with a plurality of radially extending vanes, two of which can be seen in Figure 2 designated by reference numeral 19. As can be seen from Figure 2, and more clearly in Figure 3, the van 19 are curved with the moulded plastics section 18 and serve to guide flow recirculating in the rear part of the hul an effective manner to cool the electric motor by dissipating heat generated thereby. The vanes 19 extend inwardl

towards the inner cylindrical ring 22 and thus also provide structural support for the hub body and hub insert.

Referring again to Figure 1, the blades of the fan will now be described. As shown in Figure 1, each blade is forwardly skewed in that the medial line of the blade (which is the line obtained by joining the points that are circumferentially equidistant from the leading edge B and the trailing edge C of the blade) is curved in a directior (root to tip) corresponding to the direction D of rotation of the fan 2. The leading and trailing edges B,C are simil curved. This skew is referred to herein as the tangential sweep of the blade and is indicated diagrammatically by t angle lambda in Figure 4a. Furthermore, each blade is secured to the hub at a dihedral angle which is illustrated diagrammatically by angle mu in Figure 4b. The dihedral angle mu is the angle between a tangent to the blade sui and the plane containing the axis of rotation.Furthermore, the blade is pitched so that the leading and trailing edg and C are not in the same plane. The pitch angle alpha is shown in Figure 4c. The variation of pitch (or chord) an with the radius of the blade moving front root to tip as shown in Figure 15.

Reference will now be made to Figure 8 to describe the tangential sweep lambda of the blade. In Figure 8, the fan origin is indicated as O and three lines are shown emanating radially from the origin, line D, line x and line E. Th leading edge of the blade, curve B, has a first part BR-BI of length x2 which extends tangentially to the line D. Tl medial line, curve A, similarly has a first part AR-AI of length x1 tangentially to the line x and the curve C defini the trailing edge has a similar part CR-CI of length x3 extending tangentially to the radial line E. The lengths x1, and x3 are preferably between 5% and 10% of the curve length.

As can be seen in Figure 8, the curved portions BR-BI and CR-CI do not extend exactly tangentially to their respective radial lines D and E over the whole of the length x2 and x3. However, these portions should be design be as close to the tangent as possible, subject to other design constraints. The variation of the portion BR-BI from tangent can hardly be distinguished in Figure 8, but the variation of the portion CR-CI is clearer. Thus, it will be understood that the term "tangential" used herein includes within its scope substantially but not necessarily compl tangential portion. As explained earlier, the provision of a linear portion at the root region of the blade increases t strength of the blade at the root portion.

In another embodiment, the points BI,AI and CI are further along their respective curves B and C, and in particul can lie any distance up to 50% of the curve length. In this embodiment, the portions CR-CI and BR-BI are skewe one direction up to the tangential point CI and the blade then skews in the opposite direction between CI and CT between BI and BT, CT and BT being the contact points of the blade tip with the outer band 8.

The points AI, BI and CI (defining the lengths x1, x2 and x3) may all be placed on the same circle defined from t fan origin 0 or may be on different circles. The preferred relationship between the values AI, BI and CI is given b with reference to the points of intersection of these curves AT, BT, CT with the outer band 8. Lines are drawn pa to the radial line x to intersect respectively the points BT, AT, CT, BI and CI. The following distances are measu from the radial line x to these lines as follows:
Y5 to the line intersecting BT
Y4 to the line intersecting AT
Y2 to the line intersecting CT
Y3 to the line intersecting BI
Y1 to the line intersecting CI

Preferably the relationship between these values is as follows:
Y2 is greater than or equal to Y1
Y4 is greater than or equal to Y3
Y5 is greater than or equal to Y4
Y6 (the distance between line D and a line running parallel to it intersecting AT) is greater than or equal to 0
Y4 is greater than Y2

However, other relationships between these values may be satisfied depending on the application of the blade, provided that there is always a portion CI, BI of the blade tangential to a radius.

Figure 9 illustrates the relationship between the chord width projection at the root 14 of the blade and that at the t 16. Ri is the radius of the hub measured from the fan origin O and theta R is the angle subtended by the points CI and BR (the root points of the trailing and leading edges). The root chord length SR is Ri theta R where theta R is radians.

The angle theta t subtended by radii intersecting the points CT,BT defines the tip chord width projection as St=R:

theta t where Rf is the outer fan radius. In the illustrated embodiment, theta R is greater than theta t and St is grea than or equal to SR.

The chord width gradually increases from the root of the blade for a distance corresponding to 50-70% of the spa the blade and then decreases continuously for the remaining 50-30% of the span of the blade. The relationship of chord width with respect to the radius of the fan (the span of the blades) is given in Figure 13. The variation of th chord angle with respect to the radius of the fan is given in Figure 15. The projected blade width follows closely t chord width as illustrated in Figure 12 and thus gradually increases from the root of the blade for a length corresponding to 50-70% of the span of the blade and then decreases continuously for the remaining 50-30% of tl span of the blade.

Figure 10 shows in section the blade 6 and its connection at its root to the hub 4 and at its tip to the band 8. Figur 46 and 10 clearly shows a variation in the dihedral angle mu such that the dihedral angle decreases with respect t radius of the fan along the span of the blade over the first 65-75% of the blade span and then stays constant for th remaining 35-25%. As an alternative to the dihedral angle remaining constant over the remaining 35-25% of the l span, it could increase slightly over this distance.

The blade described herein provides a downstream variable axial flow velocity which increases continuously fron hub 4 to the outermost tip 16 of the blade, with the maximum axial velocities occurring over the span of the blade the outermost 25-35% of the blade. The variation in velocity with respect to radius is shown in Figure 11. This variation enables the performance efficiency of the fan to be optimised whilst reducing the noise level.

The blade thickness decreases spanwise of the blade and also varies across the chord length. Figures 10 and 14 sh the variation of blade thickness across the dihedral plane and across the chord width of the blade. The blade thick has been calculated to optimally reduce the weight of the blade, aerodynamic (aerobic) losses and noise.

While the preferred embodiment of the present invention has been described, it will be apparent that other variati alterations or modifications are possible without departing from the main principles of the invention and such modifications, alterations and variations are intended to fall within the scope of the appended claims.

In particular, the fan described herein can be used without an outer band 8. Furthermore, although a preferred me of manufacture is by injection moulding of a plastics section which provides the hub, blades and band integrally, manufacturing processes are possible using a combination of plastics and metal as known in the art.

Claims of corresponding document: **EP0583091**

1. A fan comprising a hub rotatable about an axis at the centre of the fan and a plurality of blades each having a r region secured to the hub and extending radially outwardly to a tip region, wherein each blade has leading and tra edges which each include a portion lying tangential to a respective radius extending from the centre of the fan.

2. A fan as claimed in claim 1, wherein the leading and trailing edge each have a portion at the root region of the blade which extends tangentially to a respective radius extending from the centre of the fan for a distance along tl length of each of the leading and trailing edges which lies between 5% and 10% of the total length, after which th leading and trailing edges curve continuously.

3.A fan as claimed in claim 1, wherein the tangential portion of the leading and trailing edges lies at a tangent poi between the root region of the blade and a point lying 50% along the length of the leading and trailing edges, the leading and trailing edges being skewed in one direction between the root region and said tangent point, the direc of skew being changed at the tangent point.

4. A fan according to claim 1, wherein each blade has a chord width at the root region, the chord being taken acrc an arc defined by the radius of the hub and the contact points of the leading and trailing edges with the hub, whic not greater than the chord width at the tip region, the chord at the tip being taken across an arc defined by the radi of the fan and the contact points of the leading and trailing edges with said tip arc.

5.A fan according to claim 2, wherein each blade has a chord width at the root region, the chord being taken acro:

arc defined by the radius of the hub and the contact points of the leading and trailing edges with the hub, which is greater than the chord width at the tip region, the chord at the tip being taken across an arc defined by the radius c fan and the contact points of the leading and trailing edges with said tip arc.

6. A fan according to claim 3, wherein each blade has a chord width at the root region, the chord being taken acrc an arc defined by the radius of the hub and the contact points of the leading and trailing edges with the hub, whic: not greater than the chord width at the tip region, the chord at the tip being taken across an arc defined by the radi of the fan and the contact points of the leading and trailing edges with said tip arc.

7.A fan according to claim 4, wherein the chord length increases from the root region of the blade over a first por of the span of the blade and then decreases over a second portion of the span of the blade.

8. A fan according to claim 5, wherein the chord length increases from the root region of the blade over a first poi of the span of the blade and then decreases over a second portion of the span of the blade.

9. A fan according to claim 6, wherein the chord length increases from the root region of the blade over a first poi of the span of the blade and then decreases over a second portion of the span of the blade.

10. A fan according to claim 7, wherein the first portion extends for a distance lying between 50-70% of the blad‹ span.

11. A fan according to claim 8, wherein the first portion extends for a distance lying between 50-70% of the blad‹ span.

12.A fan according to claim 9, wherein the first portion extends for a distance liying between 50-70% of the blad‹ span.

13. A fan according to claim 1, wherein each blade has a surface which is curved so that the dihedral angle varies along the span of the blade moving from the root to the tip, the dihedral angle being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan.

14. A fan according to claim 13, which is manufactured as a single, integral unit.

15. A fan according to claim 13 wherein the dihedral angle decreases moving from the root to the tip over a first portion of the span of the blade, said first portion being between 65% and 75% of the total span and then stays constant or gradually increases for the remainder of the span of the blade.

16.A fan according to claim 4, wherein each blade has a surface which is curved so that the dihedral angle varies along the span of the blade moving from the root to the tip, the dihedral angle being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan, the dihedral an decreasing moving from the root to the tip over a first portion of the span of the blade, said first portion being bet 65-75% of the total span and then staying constant or gradually increasing for the remainder of the span of the blɛ

17.A fan according to claim 7, wherein each blade has a surface which is curved so that the dihedral angle varies along the span of the blade moving from the root to the tip, the dihedral angle being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan, the dihedral an decreasing moving from the root to the tip over a first portion of the span of the blade, said first portion being bet 65-75% of the total span and then staying constant or gradually increasing for the remainder of the span of the blɛ

18. A fan according to claim 1, wherein the tip regions of the blade are secured to an outer annular band.

19. A fan according to claim 4, wherein the tip regions of the blade are secured to an outer annular band.

20.A fan according to claim 7, wherein the tip regions of the blade are secured to an outer annular band.

21. A fan according to claim 1 which is formed as a single, integral unit.

22. A fan comprising a hub rotatable about an axis at the centre of the fan and a plurality of blades each having a region secured to the hub and extending radially outwardly to a tip region, wherein each blade has a chord width : the root region, the chord being taken across an arc defined by the radius of the hub and the contact points of the

leading and trailing edges with the hub which is not greater than the chord width at the tip region, the chord at the being taken across a tip arc defined by the radius of the fan and the contact points of the leading and trailing edge with said tip arc.

23. A fan as claimed in claim 22, wherein the chord length increases from the root region of the blade over a first portion of the span of the blade and then decreases rapidly over a second portion of the span of the blade.

24. A fan as claimed in claim 23, wherein the first portion extends for a distance lying between 50-70% of the bla span.

25.A fan comprising a hub rotatable about an axis at the centre of the fan and a plurality of blades each having a r region secured to the hub and extending radially outwardly to a tip region, wherein each blade has a surface which curved so that the dihedral angle varies along the span of the blade moving from the root to the tip, the dihedral a being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan, the dihedral angle decreasing moving from the root to the tip over a first portion of the span of blade, said first portion being between 65-75% of the total span and then staying constant for the remainder of the span of the blade.

26.A fan as claimed in claim 22, wherein each blade has a surface which is curved so that the dihedral angle varie along the span of the blade moving from the root to the tip, the dihedral angle being the angle defined between a plane tangential to the surface of the blade and the plane containing the axis of rotation of the fan, the dihedral an decreasing moving from the root to the tip over a first portion of the span of the blade, said first portion being bet 65-75% of the total span and then gradually increasing for the remainder of the span of the blade.

27.A fan comprising a hub rotatable about an axis at the centre of the fan and a plurality of blades each having a r region secured to the hub and extending radially outwardly to a tip region, wherein each blade has the following characteristics:
a) the leading and trailing edges each have a portion extending tangentially to a respective radius extending from centre of the fan, said portion lying between 5% and 10% of the length of each edge;
b) the blade surface is curved so that the dihedral angle varies along the span of the blade moving from the root tc tip; and
c) the chord width at the root region is not greater than the chord width at the tip region.

28.A fan comprising a hub rotatable about an axis and a plurality of blades each having a root region secured to tl hub and extending radially outwardly to a tip region, the fan further comprising an annular band having an axially extending part and a radially extending annular region to which the tip region of each of said plurality of blades is secured, wherein each blade is secured to the band with a leading edge of the blade extending tangentially to the radially extending portion.

29. A fan according to claim 18 or 19 wherein the outer annular band has an axially extending part and an annula radially extending part, each blade being secured to the band with a leading edge thereof extending tangentially tc radially extending part of the outer annular band.

30. A fan according to claim 18 wherein the outer annular band has an axially extending part extending from a re. the fan to a front of the fan and wherein a plane passing through the rear of the hub perpendicular to the axis of rotation is spaced from a plane passing through the rear of the outer annular band by a distance which varies in th range 0-50% of the axial length of the band.
